US010354768B2

(12) **United States Patent**
Karlen et al.

(10) **Patent No.: US 10,354,768 B2**
(45) **Date of Patent: Jul. 16, 2019**

(54) **RADIOGRAPHIC AND COMPUTED TOMOGRAPHY INSPECTION ANTI-COUNTERFEIT SECURITY**

(71) Applicant: **Hamilton Sundstrand Corporation**, Charlotte, NC (US)

(72) Inventors: **Eric Karlen**, Rockford, IL (US); **William Louis Wentland**, Rockford, IL (US)

(73) Assignee: **HAMILTON SUNSTRAND CORPORATION**, Charlotte, NC (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/402,577**

(22) Filed: **Jan. 10, 2017**

(65) **Prior Publication Data**

US 2018/0197645 A1 Jul. 12, 2018

(51) **Int. Cl.**
G21F 3/00 (2006.01)
G21F 1/08 (2006.01)

(52) **U.S. Cl.**
CPC . ***G21F 3/00*** (2013.01); ***G21F 1/08*** (2013.01)

(58) **Field of Classification Search**
CPC G21F 1/00; G21F 1/02; G21F 1/04; G21F 1/042; G21F 1/06; G21F 1/08; G21F 1/12
USPC 250/505.1, 506.1, 515.1, 517.1, 518.1, 250/519.1
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,893,413	B1 *	2/2011	Appleby	B29C 33/302 250/505.1
8,084,855	B2	12/2011	Lower et al.	
8,344,485	B1	1/2013	Lee	
8,428,216	B2	4/2013	Dennerlein et al.	
8,871,310	B2	10/2014	Hyeon et al.	
2002/0179860	A1 *	12/2002	Smith	G21F 1/106 250/515.1
2011/0291032	A1 *	12/2011	Sun	H01B 1/22 250/515.1
2012/0085925	A1 *	4/2012	Kasuya	B82Y 10/00 250/453.11
2014/0091241	A1 *	4/2014	Rabiei	B22F 3/1112 250/518.1
2014/0284503	A1 *	9/2014	Stevick	C22C 45/10 250/515.1
2016/0203594	A1	7/2016	Morard et al.	

(Continued)

FOREIGN PATENT DOCUMENTS

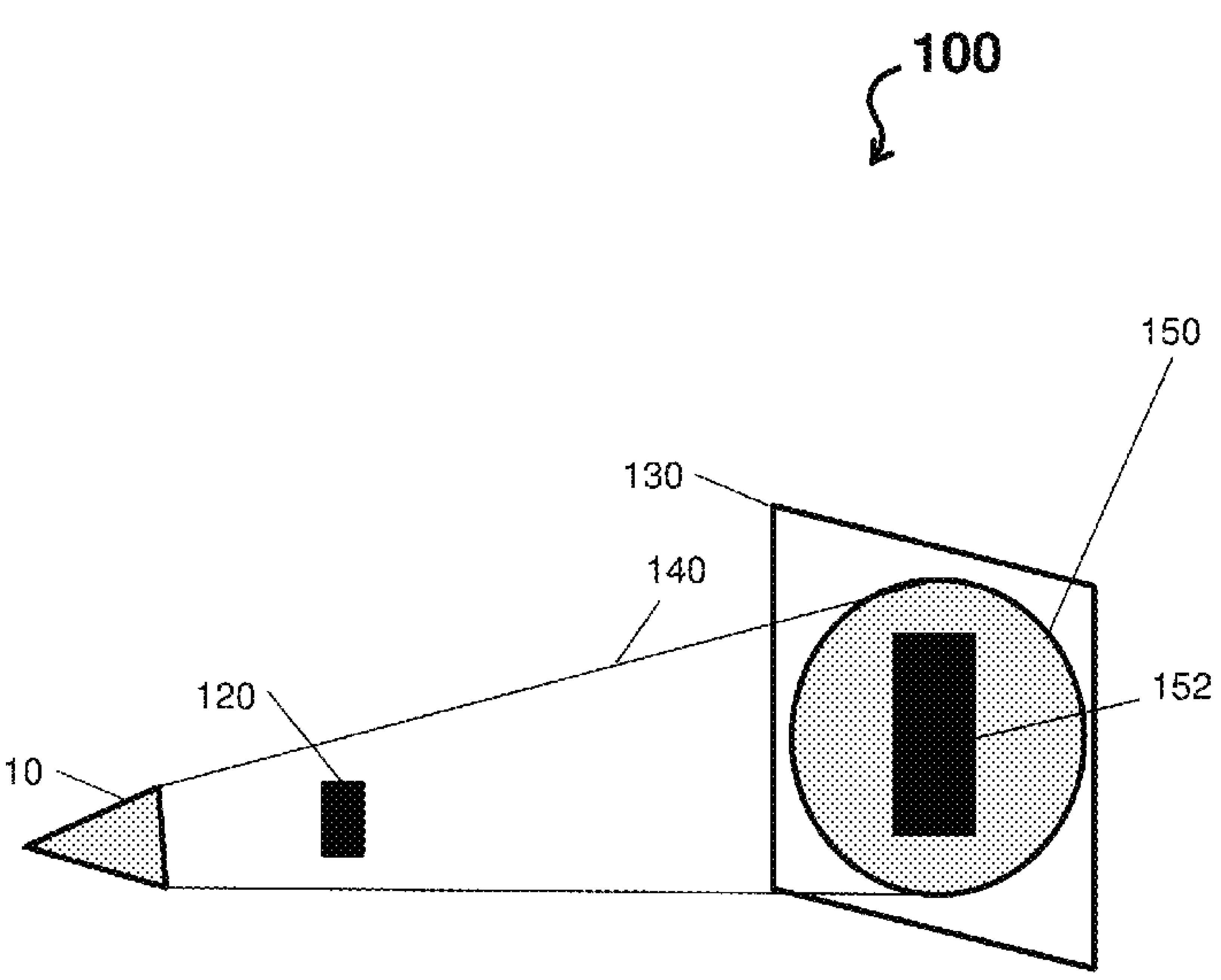
CN	203720109	U	7/2014
WO	2015077471	A1	5/2015
WO	2016073571	A2	5/2016

Primary Examiner — Jason L McCormack
(74) *Attorney, Agent, or Firm* — Cantor Colburn LLP

(57) **ABSTRACT**

A structure for preventing a scan by a beam is provided. The structure includes a primary material forming the structure. The primary material includes a first mass attenuation coefficient enabling the primary material to be penetrated by the beam. The structure also includes a matrix of dense particles within the primary material. The dense particles include secondary materials different than the primary material. The secondary materials comprise a subsequent mass attenuation coefficient that is greater than the first mass attenuation coefficient of the primary material. The subsequent mass attenuation coefficient enables the dense particles to attenuate the beam to distort the scan.

7 Claims, 6 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2016/0229120	A1	8/2016	Levine et al.
2016/0327660	A1	11/2016	Harding

* cited by examiner

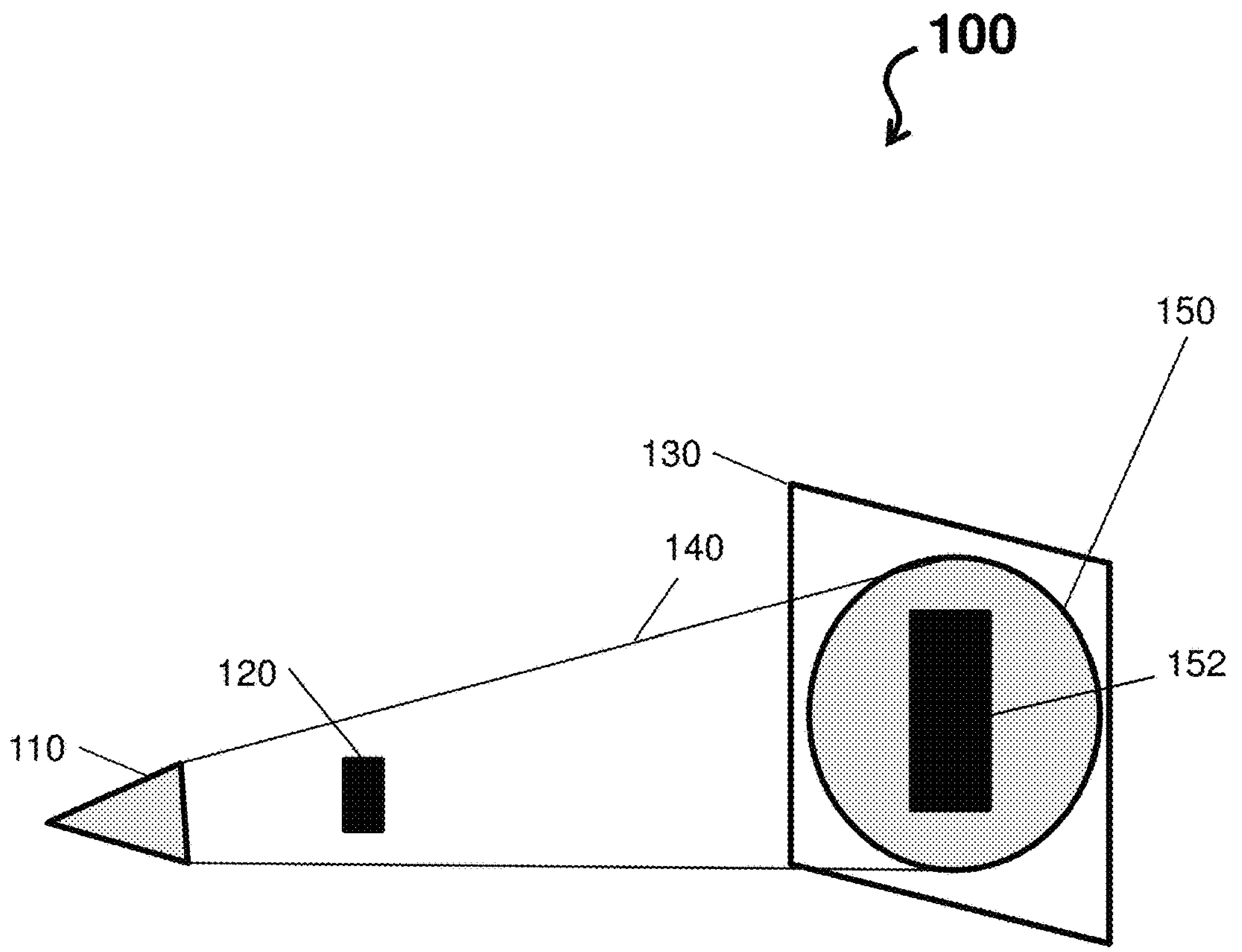


FIG. 1

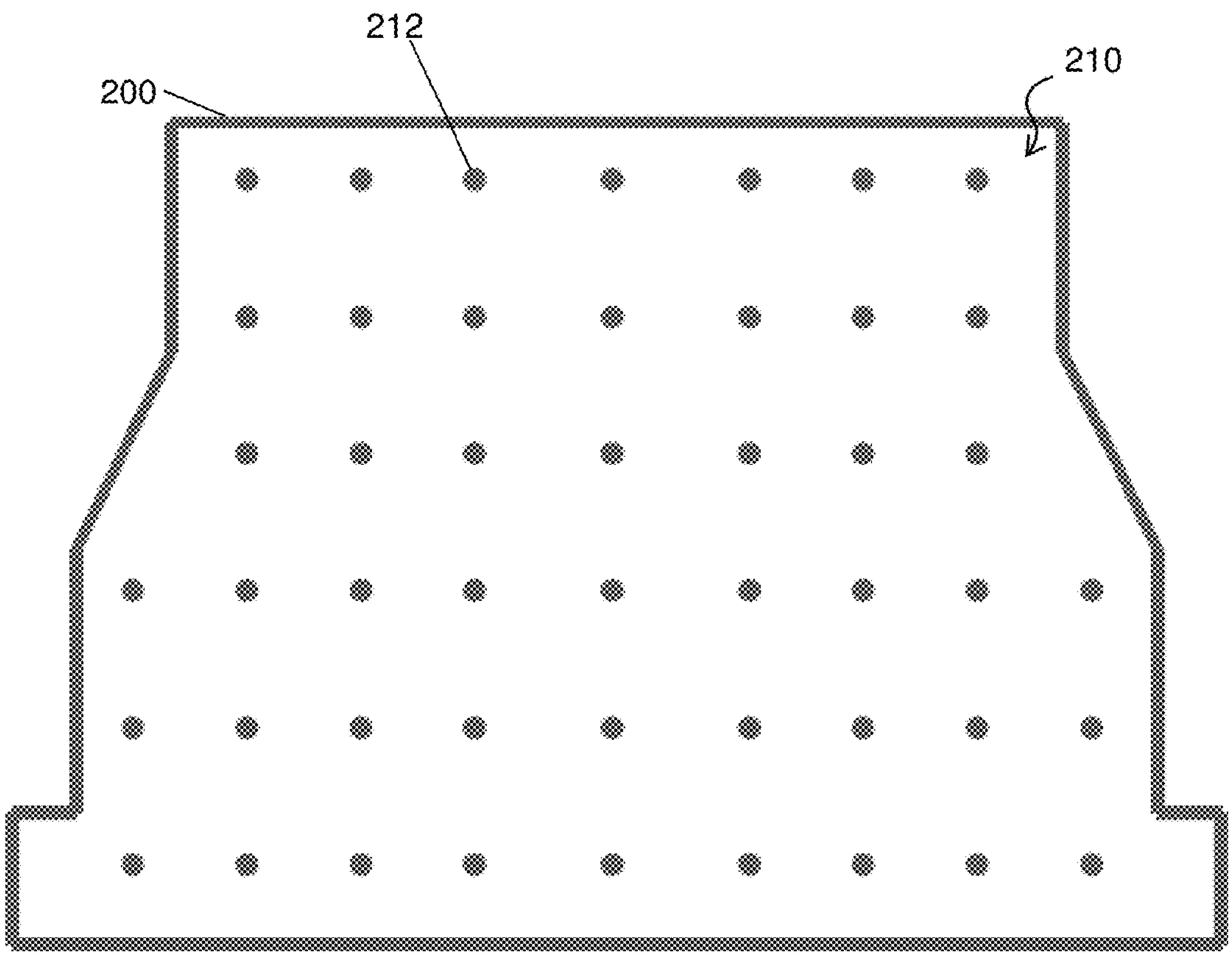


FIG. 2

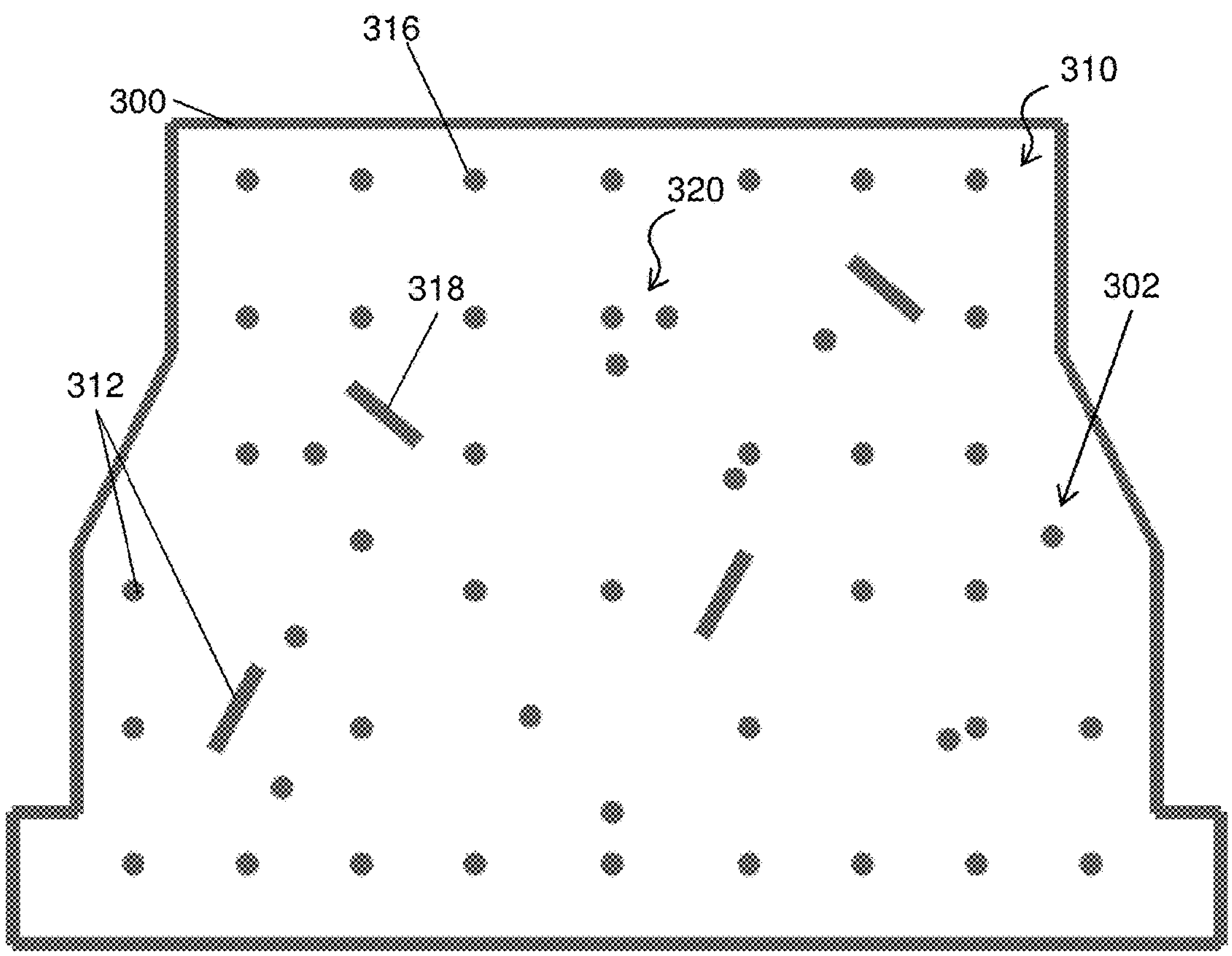


FIG. 3

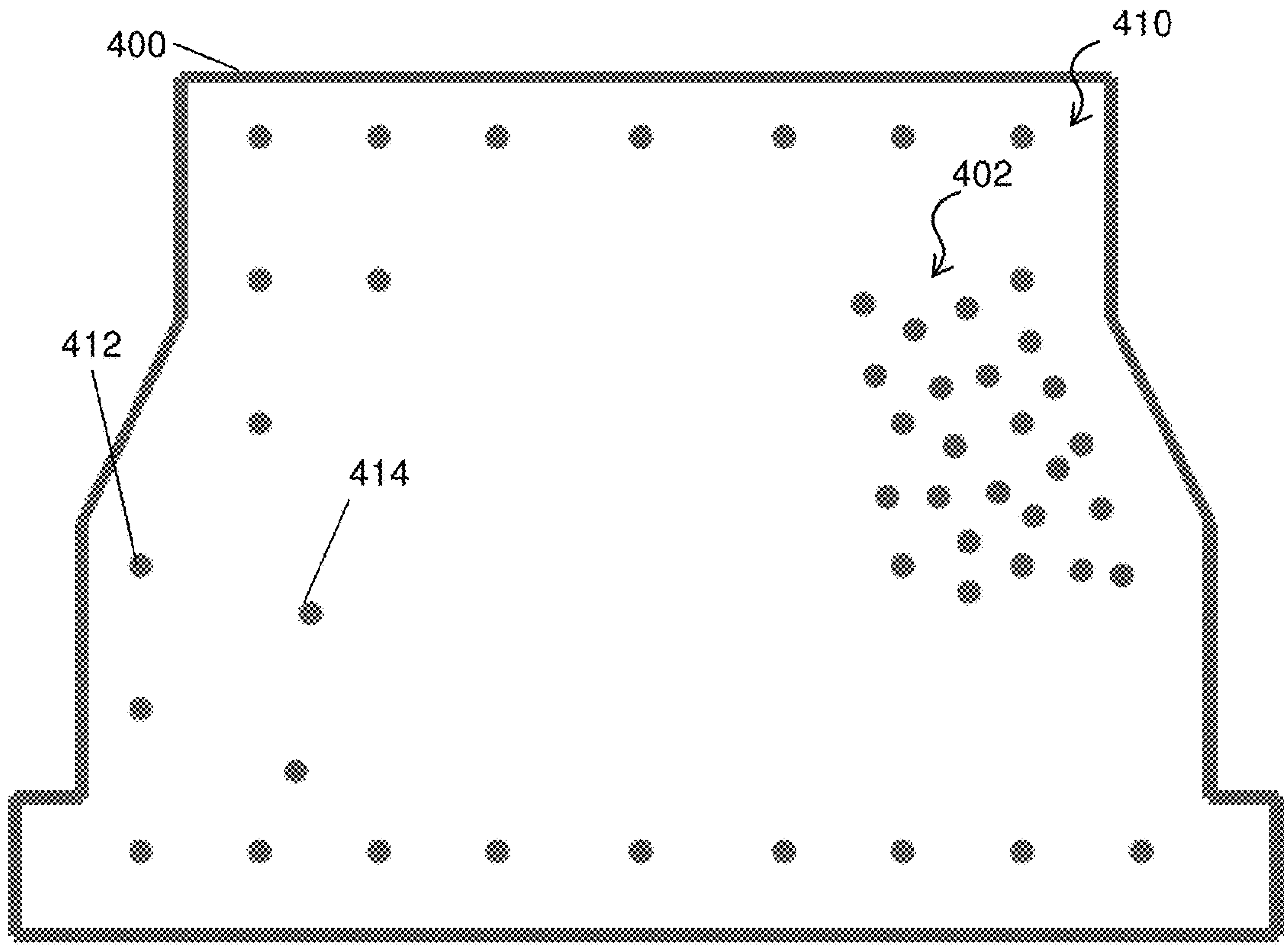


FIG. 4

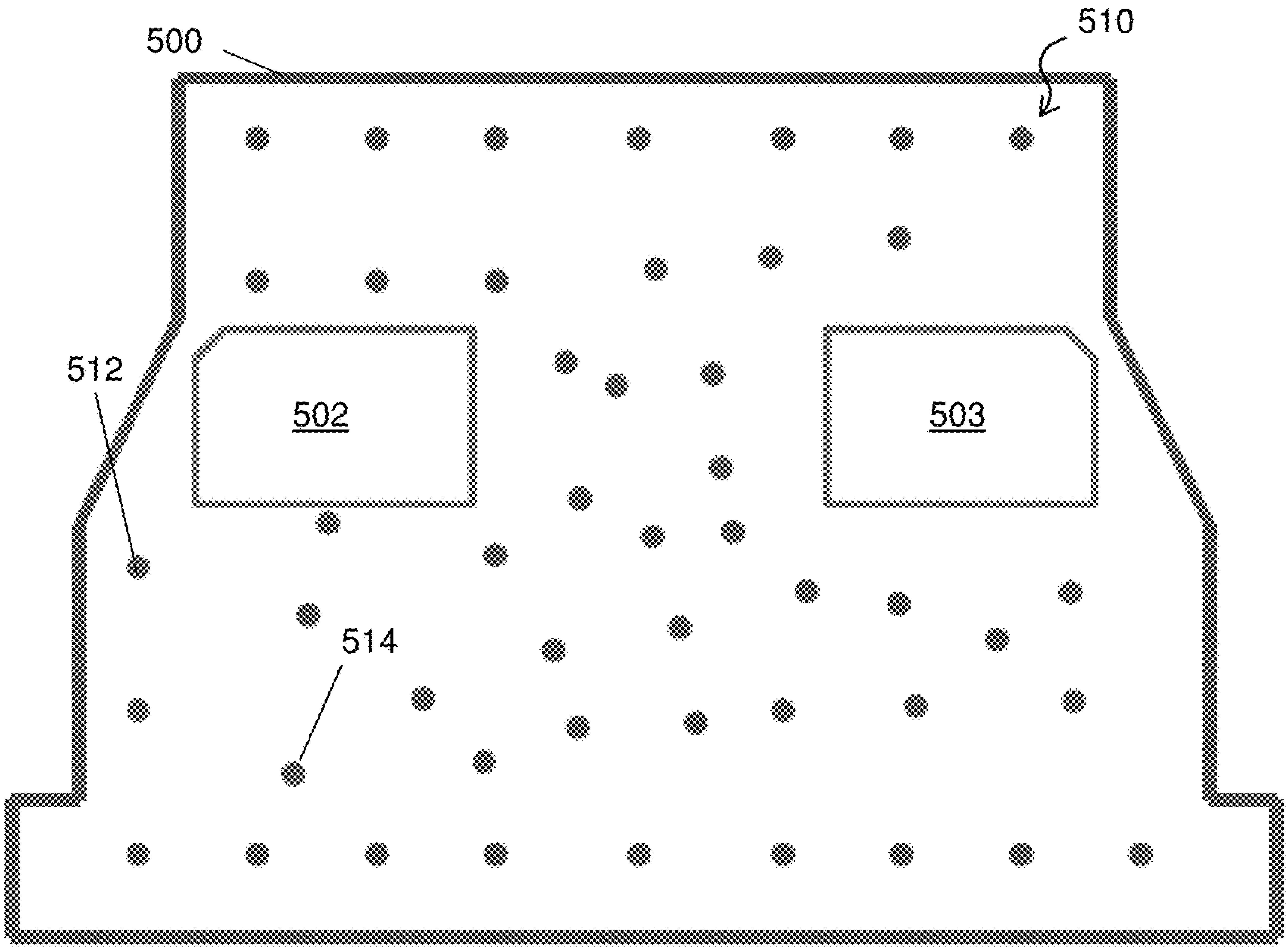


FIG. 5

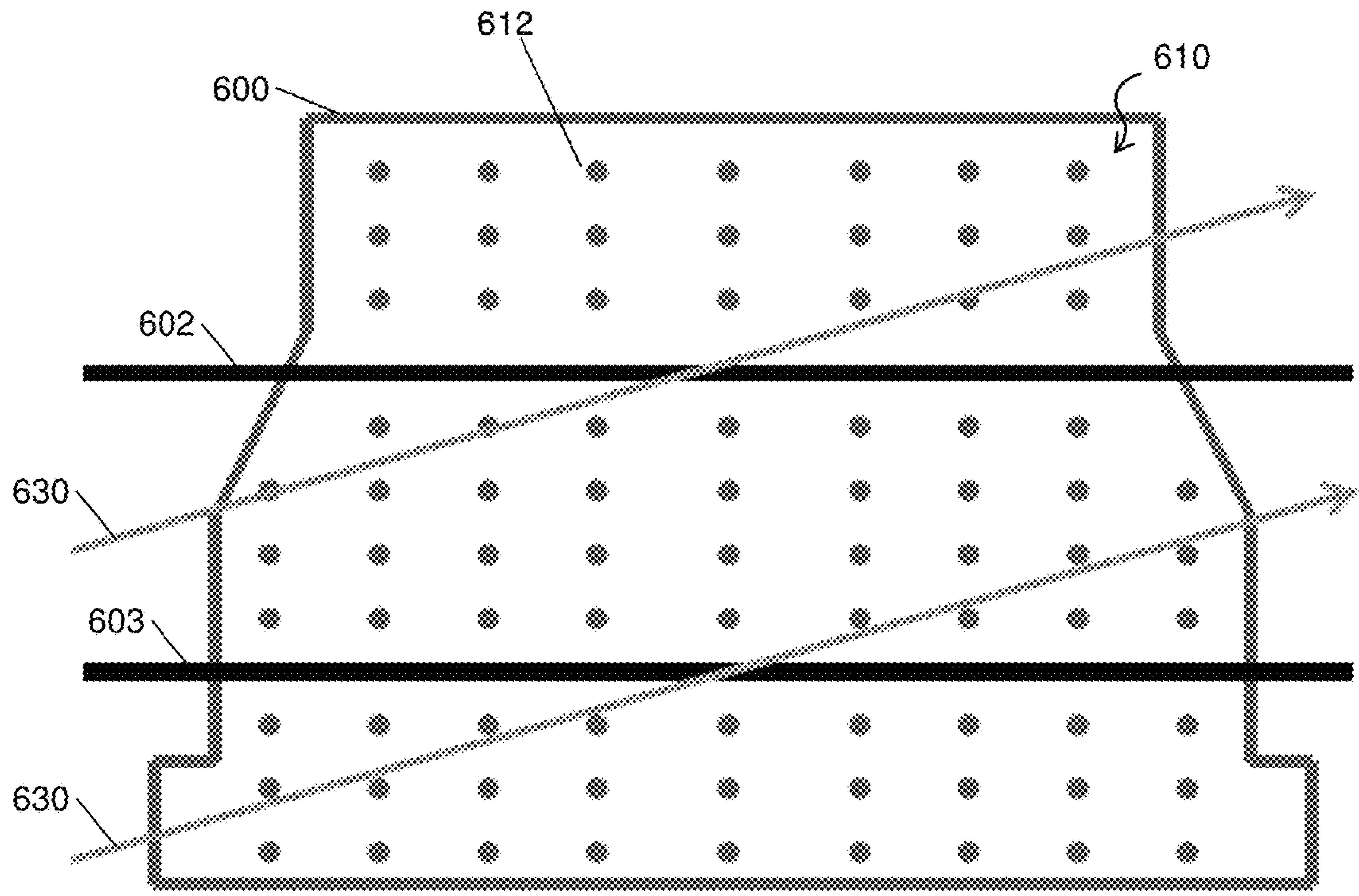


FIG. 6

RADIOGRAPHIC AND COMPUTED TOMOGRAPHY INSPECTION ANTI-COUNTERFEIT SECURITY

BACKGROUND

With respect to manufacturing integrated systems and solutions, along with components, parts, and tools therein, there is a risk in production (and for aftermarket components) of counterfeit parts entering the supply chain. Counterfeit parts are produced from reverse engineering methods. As the reverse engineering methods make technology advancements, protecting sensitive intellectual property related to the integrated systems and solutions, along with components, parts, and tools therein, is in greater need.

BRIEF DESCRIPTION

In accordance with one or more embodiments, a structure is provided. The structure includes a primary material forming the structure. The primary material includes a first mass attenuation coefficient enabling the primary material to be penetrated by the beam. The structure also includes a matrix of dense particles within the primary material. The dense particles include secondary materials different than the primary material. The secondary materials comprise a subsequent mass attenuation coefficient that is greater than the first mass attenuation coefficient of the primary material. The subsequent mass attenuation coefficient enables the dense particles to attenuate the beam to distort the scan.

In accordance with one or more embodiment or the structure embodiment above, the primary material can comprise aluminum and the one or more secondary materials can comprise tungsten, copper, nickel, or iron.

In accordance with one or more embodiment or any of the structure embodiments above, the one or more secondary materials can comprise crystal particles.

In accordance with one or more embodiment or any of the structure embodiments above, the one or more secondary materials can comprise round spheres.

In accordance with one or more embodiment or any of the structure embodiments above, the one or more secondary materials can comprise oblong shapes.

In accordance with one or more embodiment or any of the structure embodiments above, the matrix of dense particles can be uniform.

In accordance with one or more embodiment or any of the structure embodiments above, the matrix of dense particles can comprise one or more secondary materials located in offset positions.

In accordance with one or more embodiment or any of the structure embodiments above, the matrix of dense particles can comprise one or more secondary materials located in at least one cluster implemented to distort a view of a design feature to the structure.

In accordance with one or more embodiment or any of the structure embodiments above, the matrix of dense particles can comprise one or more vacant areas that include no dense particles to reveal a view of a design feature to the structure.

In accordance with one or more embodiment or any of the structure embodiments above, the matrix of dense particles can comprise one or more vacant areas that include no dense particles to mislead a scan and analysis.

In accordance with one or more embodiment or any of the structure embodiments above, the matrix of dense particles can comprise one or more gaps to enable geometric dimensioning and tolerancing measurements and inspection of critical areas of the structure.

In accordance with one or more embodiment or any of the structure embodiments above, the structure can comprise a component, a part, or a tool utilized in an electro-mechanical system of an aircraft.

In accordance with one or more embodiment or any of the structure embodiments above, the primary material can be layered via additive manufacturing technologies to form the structure.

In accordance with one or more embodiment or any of the structure embodiments above, the primary material can be produced via casting technologies to form the structure.

BRIEF DESCRIPTION OF THE DRAWINGS

The following descriptions should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike:

FIG. **1** depicts a beam detection system in accordance with one or more embodiments;

FIG. **2** depicts a uniform matrix of dense materials in a structure in accordance with one or more embodiments;

FIG. **3** depicts a modified matrix of dense materials including offset positions in a structure in accordance with one or more embodiments;

FIG. **4** depicts a modified matrix of dense materials including clustering in a structure in accordance with one or more embodiments;

FIG. **5** depicts a modified matrix of dense materials including one or more vacant areas in a structure in accordance with one or more embodiments; and

FIG. **6** depicts a modified matrix of dense materials including one or more gaps in a structure in accordance with one or more embodiments.

DETAILED DESCRIPTION

A detailed description of one or more embodiments of the disclosed apparatus and method are presented herein by way of exemplification and not limitation with reference to the Figures.

Embodiments herein relate to a network or matrix of dense particles within a structure of a sample that deter or prevent x-ray and computed tomography being used to copy the structure through reverse engineering and/or that aid in inspection and identification of the structure. The sample can be a component, a part, and/or a tool utilized in a larger system, such as an electro-mechanical system of an aircraft. The technical effects and benefits of the network or matrix of dense particle embodiments include increased confidence in security of structure design, reduced risk of counterfeit parts entering the supply chain and strengthening of a base material of the structure.

Turning now to FIG. **1**, a beam detection system **100** is depicted according to one or more embodiments. As shown in FIG. **1**, the beam detection system **100** includes a beam source **110**, a sample **120**, and a detector **130**, along with a beam **140** and an image **150**. The beam detection system **100** can be an imaging system and process that creates visual representations of an interior of the sample **120** for analysis. The analysis can support protection from reverse engineering and/or identification of the sample **120**. Example types of the beam detection system **100** include X-ray radiography, magnetic resonance imaging, ultrasound imaging, tactile imaging, thermography, etc.

In operation, the beam source **110** projects the beam **140** across the sample **120** so that the detector **130** receives the image **150**. For example, the beam source **110** projects, as the beam **140**, one or more radio waves (or other medium) according to a type of beam detection system **100**. The sample **120** can be on and rotated by a turn-table so that multiple images **150** are captured as the sample **120** spins. The detector **130** receives the image **150**, which includes an imaged interior **152** of the sample **120**. In a non-limiting embodiment, a computed tomography inspection using a highly collimated fan beam and collimated linear diode array (e.g., beam **140**) would penetrate the structure **120** unabated to perform geometric dimensioning and tolerancing measurements and inspection of critical areas of the structure **120**.

The imaged interior **152** can detail a structure of the sample **120**. The structure of the sample **120** can be produced and manufactured through additive manufacturing technologies. Additive manufacturing technologies can build the sample **120** by adding layer-upon-layer of primary materials, whether the material is plastic, metal, etc. In an alternative embodiment, the structure of the sample **120** can be produced and manufactured through casting. Thus, the primary material is layered via additive manufacturing technologies to form the structure itself. However, if the structure of the sample **120** includes a network or a matrix of dense particles, then the structure the sample **120** inherently deters or prevents the beam detection system **100** from being used to copy the sample **120**. Additive manufacturing technologies can include the network or the matrix of dense particles into the sample **120** by adding secondary materials that are different from the primary materials.

The dense particles can comprise any material with a greater mass attenuation coefficient than the primary material surrounding the matrix would also work. The mass attenuation coefficient characterizes how easily material can be penetrated by the beam **140**. A large attenuation coefficient quickly "attenuates" (weakens) the beam as it passes through the material, thereby distorting the image **150**. A small attenuation coefficient allows the material to be relatively transparent to the beam **150**. For instance, with respect to a dense particle or material within a less dense primary material, the denser particle causes significant attenuation of an x-ray creating noise in the image **150**. In a non-limiting embodiment, if the primary material is aluminum, the dense particles can include be one or more of tungsten, copper, nickel, and iron. In a non-limiting embodiment, the dense particles can be crystal particles, such as a Lutetium Aluminum Garnet crystal material, that can provide a diffraction pattern. The network or the matrix of dense particles is further described with respect to FIGS. **2-6**.

FIG. **2** depicts a structure **200** comprising a uniform matrix of dense materials **210** in accordance with one or more embodiments. The uniform matrix of dense materials **210** is an example of the network or the matrix of dense particles. The uniform matrix of dense materials **210** includes a plurality of crystal particles **212** distributed in three-dimensional grid, each of which causes scattering of the beam **140** during operations of the beam detection system **100**. In this way, a reconstructed volume based on a plurality of imaged interiors **152** of the structure **200** would contain a significant amount of noise (e.g., due to the scattering) that would not easily be evaluated or reverse engineered. Note that the plurality of crystal particles **212** can be discrete round spheres according to one or more embodiments. Also, in a non-limiting embodiment, the structure of the structure **200** can be produced and manufactured through casting, thereby providing the dense particles in a non-uniform distribution within the structure **200**.

FIG. **3** depicts a structure **300** comprising a modified matrix of dense materials **310** including offset positions **302** in accordance with one or more embodiments. The modified matrix of dense materials **310** is an example of the network or the matrix of dense particles as a randomized matrix. The modified matrix of dense materials **310** includes a plurality of crystal particles **312** distributed in three-dimensional grid, each of which causes scattering of the beam **140** during operations of the beam detection system **100**. A portion of the modified matrix of dense materials **310** is located in offset positions, as shown by crystal particle **302**. Note that the plurality of crystal particles **312** can be discrete round spheres, as shown by crystal particle **316**, or have oblong shapes, as identified by crystal particle **318**, according to one or more embodiments. Grouping of particles, as identified by crystal particle **320**, can actually enhance or create greater noise and scattering within the image **150**. The technical effects and benefits of the modified matrix of dense materials **310** include preventing the focusing on the dense particles when separating gray values from the data set.

FIG. **4** depicts a structure **400** comprising a modified matrix of dense materials **410** including clustering **402** in accordance with one or more embodiments. The modified matrix of dense materials **410** includes a plurality of crystal particles **412** distributed in three-dimensional grid, each of which causes scattering of the beam **140** during operations of the beam detection system **100**. A portion of the modified matrix of dense materials **410** is located in offset positions, as shown by crystal particle **414**. Note that the plurality of crystal particles **412** can be discrete round spheres, as shown by crystal particles **412** and **414**, according to one or more embodiments. Grouping of particles, as identified by crystal particle **402** (at least one cluster), can be implemented to distort the view of a sensitive design feature or internal component to an assembly.

FIG. **5** depicts a structure **500** comprising a modified matrix of dense materials **510** one or more vacant areas **502** and **503** in accordance with one or more embodiments. The modified matrix of dense materials **510** includes a plurality of crystal particles **512** distributed in three-dimensional grid, each of which causes scattering of the beam **140** during operations of the beam detection system **100**. A portion of the modified matrix of dense materials **510** is located in offset positions, as shown by crystal particle **514**. Note that the plurality of crystal particles **512** can be discrete round spheres, as shown by crystal particles **512** and **514**, according to one or more embodiments. The modified matrix of dense materials **510** can include no particles, as indicated by vacant area **502**, near the sensitive component so that the sensitive component can be visible with its location (e.g., scanning can reveal the internal part). The modified matrix of dense materials **510** can include no particles, as indicated by vacant area **503**, as a red-herring to mislead a scan and analysis.

FIG. **6** depicts a structure **600** comprising a modified matrix of dense materials **610** including one or more gaps **602** and **603** in accordance with one or more embodiments. The modified matrix of dense materials **610** includes a plurality of crystal particles **612** distributed in three-dimensional grid, each of which causes scattering of the beam **140** during operations of the beam detection system **100**. In one or more embodiments, the operations of the beam detection system **100** can include a highly collimated fan beam and collimated linear diode array to penetrate the structure **600** unabated with respect to the one or more gaps **602** and **603** to enable geometric dimensioning and tolerancing measurements and inspection of critical areas of the structure **600**. For example, the plurality of crystal particles **612** enabled an x-ray inspection performed at an angle **630**.

In a non-limiting embodiment, the network or the matrix of dense particles can include one or more of any of the features described with respect to FIGS. **2-6**. For example, the network or the matrix of dense particles can include offset positions within a uniform matrix and included clustering, one or more vacant areas, and one or more gaps.

The term "about" is intended to include the degree of error associated with measurement of the particular quantity based upon the equipment available at the time of filing the application. For example, "about" can include a range of ±8% or 5%, or 2% of a given value.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present disclosure. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, element components, and/or groups thereof.

While the present disclosure has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the present disclosure. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from the essential scope thereof. Therefore, it is intended that the present disclosure not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this present disclosure, but that the present disclosure will include all embodiments falling within the scope of the claims.

What is claimed is:

1. A structure for preventing a scan by a beam, the structure comprising:

a primary material forming the structure, the primary material comprising a first mass attenuation coefficient enabling the primary material to be penetrated by the beam; and

a matrix of particles within the primary material to provide scattering or attenuating of the beam to distort the scan,

wherein the particles comprise one or more secondary materials different than the primary material,

wherein the one or more secondary materials comprises a plurality of crystal particles distributed in three-dimensional modified matrix with a varying number of the plurality of crystal particles located in offset positions and with a varying number of grouped particles, a subset of the plurality of crystal particles comprising oblong shaped crystal particles, and a second subset of the plurality of crystal particles comprises round sphered crystal particles,

wherein the one or more secondary materials comprises at least one subsequent mass attenuation coefficient that is greater than the first mass attenuation coefficient of the primary material, and

wherein the at least one subsequent mass attenuation coefficient enables the particles to scatter or attenuate the beam to distort the scan comprising the varying number of the grouped particles being positioned within the structure to prevent a view of a design feature or internal component to the structure by the scan,

wherein the matrix of particles comprises one or more gaps to enable geometric dimensioning and tolerancing measurements and inspection of critical areas of the structure, one or more vacant areas that include no particles to reveal a view of a first design feature of the structure, one or more secondary materials located in at least one cluster implemented to distort a view of a second design feature of the structure, and one or more vacant areas that include no particles to mislead a scan and analysis of the view of the first and second design features.

2. The structure of claim **1**, wherein the primary material comprises aluminum and the one or more secondary materials comprises tungsten, copper, nickel, or iron.

3. The structure of claim **1**, wherein the matrix of particles is uniform.

4. The structure of claim **1**, wherein the matrix of particles comprises one or more secondary materials located in offset positions.

5. The structure of claim **1** comprises a component, a part, or a tool utilized in an electro-mechanical system of an aircraft.

6. The structure of claim **1**, wherein the primary material is layered via additive manufacturing technologies to form the structure.

7. The structure of claim **1**, wherein the primary material is produced via casting technologies to form the structure.

* * * * *